THE STRATIGRAPHICAL AND STRUCTURAL GEOLOGY OF THE DEVONIAN ROCKS OF THE SOUTH COAST OF NEW SOUTH WALES.

By Ida A. Brown, B.Sc., Linnean Macleay Fellow of the Society in Geology.

(Plates xxx–xxxiv; seven Text-figures.)

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Introduction and General Geology.—Previous Records.—Geology of the Eden District.—Other Occurrences of Devonian Rocks on the South Coast.—Petrology of the Igneous Rocks.—Age of the Basal Rhyolites.—Correlation of the Devonian Rocks of the South Coast.—Tectonic History and Palaeogeography.—Summary

Introduction and General Geology.

A brief general account of several occurrences of Devonian rocks on the far South Coast of New South Wales has been given in a paper by the writer (1930), in which most of the known earlier literature on the subject is recorded.

The present paper describes in more detail the stratigraphical and structural relationships of the Devonian system as represented on the far South Coast of New South Wales, and suggests certain correlations with occurrences of similar age in other parts of south-eastern Australia.

Recent field work has shown that there is a much more extensive development of Devonian rocks in this region than was supposed formerly, when geological examination had been confined to the section along the main coast road or Prince's Highway, which runs over pre-Devonian sediments and granitic rocks for the greater part of two hundred miles; the country to the west of the road is not easily accessible.

It is now known that a belt of Devonian rocks runs from the coast south of Eden through Wolumla, Yourie, Nerrigundah and thence northwards across the Deua River, through the Clyde Mountain and on towards Yalwal. This general trend of Devonian rocks is suggested in the writer's previous paper (1930, p. 154), and is shown more clearly on the map accompanying the present paper.

It has not been found practicable to trace the beds continuously in the field owing to the mountainous and inaccessible nature of the country. The sequence has been examined in some detail in the Eden district, where the rocks have suffered least disturbance by post-Devonian earth movements; the knowledge thus obtained provided a key to the interpretation of various sections examined across the geosyncline to the north, as will be obvious from a consideration of the accompanying maps and sections.

It is proposed, therefore, to give an account of the geology of the Eden district, followed by descriptions of areas and sections to the north, and finally to suggest correlation with other areas in New South Wales and Victoria.

Previous Records.

Earlier descriptions of the geology of this area are mentioned in the writer's previous paper (1930). Of these, the most pertinent are the works of the late J. E. Carne, published in the Annual Reports of the Department of Mines and Agriculture, New South Wales, for 1896 and 1897. These include "Preliminary Notes on the Yowaka or Pambula Goldfield" (1896, pp. 107–122), "Report on Goldfind, Wolumla" (1896, p. 122), "Report on the Geology and Mineral Resources of the South-east Border of New South Wales between Cape Howe and the Head of the Murray River" (1897, pp. 151–160), and "Notes on the Geology and Auriferous Deposits of the Wolumla Goldfield" (1897, pp. 162–167).

These reports are essentially of an economic nature, but contain valuable information concerning the stratigraphy of the district. On account of more extended field-work the writer places an interpretation on many of the facts of field-occurrence, which differs from that of Mr. Carne, but this in no wise tends to diminish her appreciation of his careful observations.

The Jingera or Whipstick bismuth and molybdenite deposits occurring in granite, which is intrusive into Devonian rocks between Pambula and Wyndham, have been described by E. C. Andrews (1916*a*.).

In his Presidential Address to the Linnean Society of New South Wales, Assistant-Professor W. R. Browne (1929, p. xix) included a brief description of the Devonian igneous rocks of the district, based on Mr. Carne's reports and a re-examination of his rock-collections.

Other references will be given in the course of the paper.

The Geology of the Eden District.

The township of Eden is situated on the shores of Twofold Bay, on the south coast of New South Wales, about 350 miles by road from Sydney, and half-way between Sydney and Melbourne.

The coastal district between the Brogo River and the Victorian Border is drained by two large rivers and their tributaries, the Bega and the Towamba Rivers, which flow from the edge of the tableland eastwards to the Pacific Ocean, while the Genoa and Wallagaraugh Rivers rise in the southern part of the area and flow southwards across the border into Victoria. The smaller coastal rivers and creeks, such as Merrimbula, Pambula and Womboyne, flow into lakes, which form a characteristic feature of the coastal topography.

The physiography of the area is being considered in a paper in the course of preparation.

The geological nature of the underlying rocks has played an important part in the physiographical and economic development of the region under consideration. In general, sedimentary rocks outcrop from the coast inland for a distance of 6 to 12 miles, and the area to the west consists mainly of granite, which produces gently undulating topography. As a result, the district has good road communication with the Monaro Tableland lying to the west.

The principal roads are from Bega to Cooma over the Brown Mountain; the Tantawangalo road from Bega to Bombala through Candelo and Cathcart; the Wyndham and Towamba roads over Big Jack Mountain to Cathcart and Bombala; and the recently constructed Mount Darragh road from Wyndham to Cathcart. In addition, the maturely dissected granite country affords easy grades for numerous roads through the districts of Pericoe, Towamba, Burragate, Wyndham,

Candelo, Wolumla, Kameruka, Bemboka, Numbugga, Bega and Brogo. The more rugged and barren country composed of sedimentary rocks offers less inducement for road-making.

The Devonian rocks of the Eden-Pambula district outcrop along the coast north and south of Twofold Bay, and have been described by W. B. Clarke (1860), E. F. Pittman (1880) and J. E. Carne (1896).

These rocks are bounded on the west by intrusive granite and unconformably overlie older Palaeozoic schists and slates. The latter outcrop between the western portion of Twofold Bay and the Victorian Border, and again between Bega and Tathra, this being the southern extension of the outcrop from the Clyde River along the coastal districts through Narooma and Bermagui.

It is the writer's intention to give a detailed account of the older Palaeozoic rocks of the coast on a future occasion; in this paper merely incidental references will be made to the pre-Devonian sediments.

The distribution of the Devonian and older rocks of the Eden district is indicated on the accompanying map, Plate xxxiii.

Three divisions of the Devonian system are represented in the Eden district, (*a*) a lower volcanic stage, consisting of acid igneous rocks; (*b*) a middle stage, containing chocolate shales, thin-bedded buff and red grits and sandstones with interbedded igneous rocks; and (*c*) an upper stage consisting chiefly of marine conglomerates, grits, sandstones and quartzites containing Upper Devonian fossils.

(*a*) *The Lower Volcanic Stage.*

Members of the volcanic stage outcrop on the Womboyne River and along its southern tributary, Watergums Creek, and form a belt about 250 yards in width running from Disaster Bay, into which the Womboyne flows, in a northerly direction to Munganno Point, on the southern side of Twofold Bay. This outcrop is bounded on the west by folded pre-Devonian sediments, but no clear vertical section of the junction has been observed on the south side of Twofold Bay.

On the northern side of the Bay this belt outcrops over the peninsula on which the Eden Lighthouse is situated, and along the cliffs for a short distance to the north. It then swings westward through the town of Eden, under the Prince's Highway, where it is obscured by Tertiary drift formation, and continues to the south of the Nethercote road through rough country to the west; its extension beyond this has not been determined.

Similar rock outcrops at Bournda Head and its adjacent "tied island", about five miles north of Merrimbula; and 9 miles east of Bega, at Tathra and on the coast to the south, similar formations occur.

The rocks under consideration include the "quartz felsite or porphyry . . . . best studied at Eden", as described by Mr. Carne (1896, p. 110), who considered that these "igneous rocks are intrusive into the older sedimentary series (Silurian?) and partly so into the Upper Series (Devonian?), for undoubtedly the former are overlaid in parts by the latter."

The present writer is of the opinion that the igneous rocks are not intrusive into the Devonian beds, but occur below Upper Devonian sediments exposed in this area, and that they represent terrestrial flows of acid lava over the eroded surface of folded older Palaeozoic sediments.

The igneous rocks outcrop always between the older, highly folded series with meridional strike and the more gently folded Devonian beds. Frequently

some type of fluxion structure is developed which dips at an angle more or less conformably with that of the adjacent Devonian sediments, and sometimes columnar structure, platy-parting and jointing, probably parallel to the cooling surface, indicate a similar direction and amount of dip; these rocks will be referred to as rhyolites.

The actual junction of the older Palaeozoic sediments and the rhyolite is exposed in several cliff-sections close to the town of Eden, and also on the northern face of cliffs, north-west of the village of Tathra. The best exposure is at the base of the cliffs immediately west of the Eden Lighthouse, where columnar rhyolite dipping at 30 degrees to the east rests on the upturned and denuded edges of folded, older Palaeozoic rocks. Similar relations are apparent at Yallumgo Cove, Mirare Point and at Tathra (Plate xxx, figures 1 and 2).

On the south side of Twofold Bay the direction of banding in the rhyolite is approximately N.40°W., and the dip of this is E.40°N. at 45°. The overlying red shales and grits along the coast near here dip E.30°N. at 35° to 40°. Beach sand obscures the base of the rhyolite on the south side of Twofold Bay.

In the neighbourhood of Eden township and at Munganno Point measurements of the rhyolites indicate a thickness of between 450 and 500 feet.

It is highly improbable that only one flow occurs, for there are lithological variations and different types of structure on various horizons. Near the base of the series a very extraordinary type of spherulitic structure is developed, in which the spherulites range from an inch up to 14 or 15 inches in diameter (Plate xxxii, fig. 1). This phase is well exposed on Mr. J. R. Logan's property, "Edrom", on the south side of Twofold Bay, and has been recorded from near Eden by Mr. Carne (1896, p. 111). Columnar structure is well developed through the main portion of the series, particularly in the cliffs near the Eden Light (Plate xxx, figs. 1, 3), and on both sides of Yallumgo Cove. Sometimes the rock is amygdaloidal, and the vesicles may contain amethystine quartz, as in the cliffs below the Roman Catholic Convent; or crystallized haematite, popularly thought to be molybdenite. Platy-parting occurs at the east of "Edrom", at Eden and at Tathra.

The petrological characters of the rocks are considered later.

(*b*) *The Middle Stage.*

Rocks of the middle stage overlie the rhyolites and outcrop at the mouth of the Womboyne River; along the coast from Disaster Bay to Munganno Point, Twofold Bay; and extend along the coast from Eden to Tura Head, north-east of Merrimbula. They may be traced inland from Eden through the Nethercote district, across the Pambula-Wyndham road on towards Wolumla.

The relation to the underlying rocks is best exposed on the south side of Twofold Bay, on the property of Mr. Logan, where conglomerates and other shallow-water beds are deposited over the eroded surface of the rhyolite (Plate xxxi, fig. 1).

A large boulder of the conglomerate on the beach close to the junction contains fragments of the rhyolite and a large spherulite, thus confirming the previous observation of the post-rhyolitic age of the conglomerate and the overlying beds which are conformable with it.

The erosional break and the slight differences in dip which have been recorded thus point to a disconformity between the two series, probably indicating vertical movement and a change from terrestrial to sub-aqueous conditions.

On the northern side of the Bay, the junction of the rhyolite and the overlying series occurs in the cliff sections near the end of Chandos Street, Eden, slightly to the north of the R.C. Convent grounds. Here the nature of the contact is not so obvious as at "Edrom". It was probably some such section as this which led Mr. Carne to believe that the "porphyry" was intrusive into the adjacent sediments. A photograph of this cliff section appears in Plate xxxi, fig. 2. The rhyolite is on the left-hand side and its junction with sediments is almost vertical in the centre of the photograph: on the rock-platform in the foreground the gently-dipping conglomerate and shaly beds are seen to overlie an eroded surface of the rhyolite, a repetition of the condition at "Edrom". There is no trace of contact metamorphism of the sediments against the rhyolite, and the possibility of faulting is discounted by the relations of the two rocks on the adjacent rock-platform. The steep junction of the two series is explained best as being due to the deposition of sediments on a slowly subsiding floor against an old cliff headland of rhyolite. The rhyolite is in contact with red beds again in a small valley (Portion 136, Parish of Bimmil) near the road from Eden to Nethercote, but their relations are obscured by cultivation. The rhyolite of Bournda is separated from the red beds by stretches of Tertiary and recent sands.

The rocks of the middle stage consist largely of the "clay-slates" of W. B. Clarke (1860), which have been described by J. E. Carne (1896, p. 110). These form conspicuous cliffs along most of the coast from Disaster Bay to the north of Merrimbula, where they are interbedded with thin bands of red, purple and buff-coloured sandstones and grits, some of which may be tuffaceous.

In the Nethercote district and to the north the sediments are interbedded with rhyolites, felsites and amygdaloidal basalts.

Typical sections of this stage are exposed east of the rhyolite at Munganno Point, at the south end of the Ocean beach at Eden, at North Head of Twofold Bay, at Lennard's Island, Pambula Heads and Merrimbula Head, and along most of the roads and tracks west of the Prince's Highway.

East of the rhyolite at Munganno Point the rocks consist of a series of alternating red shales and yellow grits, whose dip is somewhat variable, the average being in a direction E.30°N. at 35° to 40°.

North of the rhyolite at Eden a similar series of interbedded red clay-slates, quartz-grits, purple, grey and buff sandstones and thin green shales dip N.30°W. at 12°, the strike swinging round in approximate conformity with that of the underlying rhyolite. On account of local folding the beds a few hundred yards to the north dip N.40°E. at 12°. From the cliff section north-east of the Convent, Miss G. Joplin, B.Sc., collected a specimen of red shale containing fragmental plant remains, some of whose pinnules show well-preserved venation, which Dr. A. B. Walkom considers are possibly fragments of *Cordaites* of Upper Devonian age.

In the Museum of the Department of Geology, the University of Sydney, are specimens of *Protolepidodendron*, similar to those described by Dr. Walkom (1928) from Yalwal. These were collected by Dr. W. G. Woolnough from the east of Eden (see These Proceedings, liii, 1928 (1929), p. xl).

There is a fair amount of local folding throughout the middle stage, which may be seen in most of the sections along the coast. The directions and amounts of dip are indicated on Plate xxxiii.

The shallow-water origin of the beds, suggested by the presence of *Cordaites*, is confirmed by the preservation of sun-cracks and fine ripple-marks in the red

shaly beds and overlying sandstones in the rock-platform north of Merrimbula Head.

This stage of the Upper Devonian is no doubt analogous to that of the Nungatta and Yambulla Ranges, near the head of the Genoa River. Of these beds, J. E. Carne (1897) writes: "This formation consists of alternations of quartz-pebble conglomerates, grits, sandstones and clay shales." "In the clay shales, which are frequently strikingly red-coloured and ferruginous, abundant obscure impressions of plant remains occur both at Yambula Peak and further west on the Genoa River. In the greenish-grey arenaceous shales and finely laminated sandstones the impressions are better preserved. Amongst a number of specimens collected at the above localities Mr. Dun was able to identify the following forms: *Archaeopteris Howitti* McCoy, *Cordaites australis* McCoy, *Sphenopteris Carnei*, sp. nov., *Pecopteris* (?) *obscura*, sp. nov."

An association of similar plant remains in the Upper Devonian beds of the Perry Basin of South-eastern Maine has been described and figured by D. White (1905, p. 68), who considers that Mr. Dun's description (1897) of "*Pecopteris* (?) *obscura*" from Genoa River leaves little room for doubt as to the identity of the latter with *Barinophyton*".

Interbedded with the sediments of the middle stage are a number of volcanic flows, which outcrop to the west of the Prince's Highway. These have not all been mapped in detail, but their approximate positions are indicated on Plate xxxiii. The detailed petrological characters are described later.

The rhyolites outcrop in the Nethercote district, along the Yowaka River and its tributaries, through the Mt. Gahan ridge, and in the neighbourhood of Lochiel. They show pronounced banding and spherulitic structures, and are usually of a cream, pink or purple colour.

The basalts are generally amygdaloidal, although the stratigraphically lowest horizon is a fairly compact rock. They are characterized by an abundance of epidote, and in places veins of fibrous asbestos and quartz occur. These characters are generally sufficient to distinguish them from the limited outcrops of Tertiary basalt in the district.

The variety of rock-types present in the middle stage, the local folding of beds, and the poor exposures of consecutive sections render the determination of the thickness of this stage somewhat difficult. Measurements indicate a thickness of between 1,500 and 2,000 feet.

(c) *The Upper Stage.*

The red beds of the Middle Stage are succeeded by an Upper Stage of massive conglomerates, sandstones and quartzites, with thin bands of red shales, which contain no volcanic rocks so far as the writer is aware. As a rule these beds are nearly horizontal or only slightly dipping. These differences in the amount of folding and the marked lithological change from fine-grained, soft red shales to coarse massive conglomerate indicate a break in the conditions of deposition amounting to a disconformity or perhaps even unconformity.

Unfortunately no clear vertical exposure of the junction is known to the writer, for the cliffs along the coast are carved out of the middle stage of red beds. Perhaps the relations may be traced by detailed work near the turn-off to Nethercote on the Prince's Highway at the Yowaka-Saltwater Bridge, or in the cliff sections on Broadwater Lagoon, but these are somewhat inaccessible.

Near the head of Bald Hills Creek, north-east of Pambula Trigonometrical Station, there is an extensive outcrop of typical amygdaloidal basalt, which is overlain by dipping red shales at a turn of the creek. Above the red shales are almost level-bedded massive purple conglomerates, more or less silicified, and strongly jointed; the vertical master-joints cut through the included pebbles and give the appearance of artificial "marble", thus probably accounting for the popular name of the locality. Somewhat similar relations occur along the Pambula River near the "Six Mile", on the road from Pambula to Wyndham, where the basalt outcrops in the bed of the river, and the overlying massive conglomerates cap the hills to the east.

It is considered that the central portion of the outcrop of the Devonian rocks between Eden and Wolumla, including the sandstones and quartzites of Bellbird Creek, the Bimmel Mountain, and the higher parts of the area between Pambula, Merrimbula and Wolumla, consist chiefly of rocks of the Upper Stage. At the southern end of this outcrop there is evidence of overlap of the basal conglomerates of the Upper Stage on the lower stages, west of the Prince's Highway, and a mile south-west of Eden.

Further evidence of the more extensive development of the Upper Stage is afforded by outliers of this stage resting directly and unconformably on the pre-Devonian sediments along a ridge followed by the Towamba road, north of the Nullica River, and also on the top of Mount Imlay (Text-fig. 1, Section 4). The older Palaeozoic series outcrops on Mount Imlay up to about 1,800 feet above sea level, above which are almost horizontal red beds, followed at the 2,100 foot level by conglomerates, grits and sandstones, with occasional bands of red shales. The Trigonometrical Station at the top (2,913 feet) is situated on a band of red shale. No igneous material has been observed by the writer in this section, and it is considered that only the upper stage is represented here. The lithological differences in the rocks comprising the mountain are responsible for the varying resistance to erosion and the resultant angle of slope, which has produced a distinct shelf at the top of the older sediments.

The thickness of the Upper Stage is estimated at about 1,200 feet, but, as the upper surface is eroded, it may have been originally much greater.

Fossils have been found in only two localities, as recorded previously by the writer (1930, p. 153). From Bellbird Creek, three miles north of Eden, the following forms have been recorded (J. E. Carne, 1897; I. A. Brown, 1930): *Rhynchonella pleurodon*, *R.* (?) *cuboides*, *Atrypa* sp. (?) *reticularis*, *Polyzoa*, *Phthonia*, *Aviculopecten* (?). W. N. Benson (1922) records *Rhynchonella primipilaris* from Wolumla Creek. The quartzites of Bellbird Creek contain worm tracks and well-preserved ripple-marks as additional evidence of their shallow-water origin.

Other Occurrences of Devonian Rocks on the South Coast.

Descriptions of other occurrences of Devonian rocks have been given by the writer (1930) and others, but, for the sake of clearness, these accounts are summarized in the following pages and some additional details are recorded.

Diagrammatic sections across the areas mentioned are given in Text-figures 1 and 2.

(*a*) *The Quaama–Cobargo District.*

The village of Quaama is situated on the Prince's Highway between Bega and Cobargo, on the granitic batholith extending from Victoria to the north of Cobargo.

About three miles east of Quaama, a tributary of the Murrah or Dry River, Pipeclay Creek, works its way along the junction of the granite and the intruded rocks. On the eastern side of Pipeclay Creek and south of the Old Bermagui Road are gently dipping sandstones and quartzites containing typical Upper Devonian fossils, determined by Mr. W. S. Dun to be *Spirifera disjuncta*, *Rhynchonella pleurodon*, *Pterinea* and *Pteronites*. The discovery of Devonian forms in this district was due in the first place to Dr. A. A. Pain, as previously recorded by the writer (1930), who has subsequently collected these fossils from other localities in the district.

There is considerable variation in the dip of these beds, no doubt on account of their proximity to the intrusive granite batholith. In the upper parts of Pipeclay Creek the rocks are almost horizontal, and consist of bluish and purple sandstones and quartzites remarkably similar to those at Bellbird Creek, north of Eden. Strong jointing is developed in a direction N.10°W.

Underlying the Upper Devonian with a strong unconformity are thin-bedded conglomerates, slates and black cherts, in which graptolites were discovered in a hill overlooking the swimming pool at Pipeclay Creek; these Ordovician rocks dip steeply to the south-west.

North of this area, towards Cobargo, the granite is in contact with Devonian sediments, but on the main road six miles east of Cobargo it intrudes steeply-dipping, sandy slates and black cherts, whose direction of strike is almost meridional. Contact altered quartzites, possibly of Devonian age, occur in the neighbourhood of Sam's Creek, near the road from Cobargo to Dignam's Creek, and similar rocks outcrop to the west near the road from Cobargo to Wandellow. Between these localities, north-west of the Narira Trigonometrical Station, Ordovician rocks outcrop, from which C. F. Laseron obtained *Diplograptus foliaceus* Murchison, *Climacograptus* sp. and *Dicellograptus* sp. (W. R. Browne, 1914, p. 194).

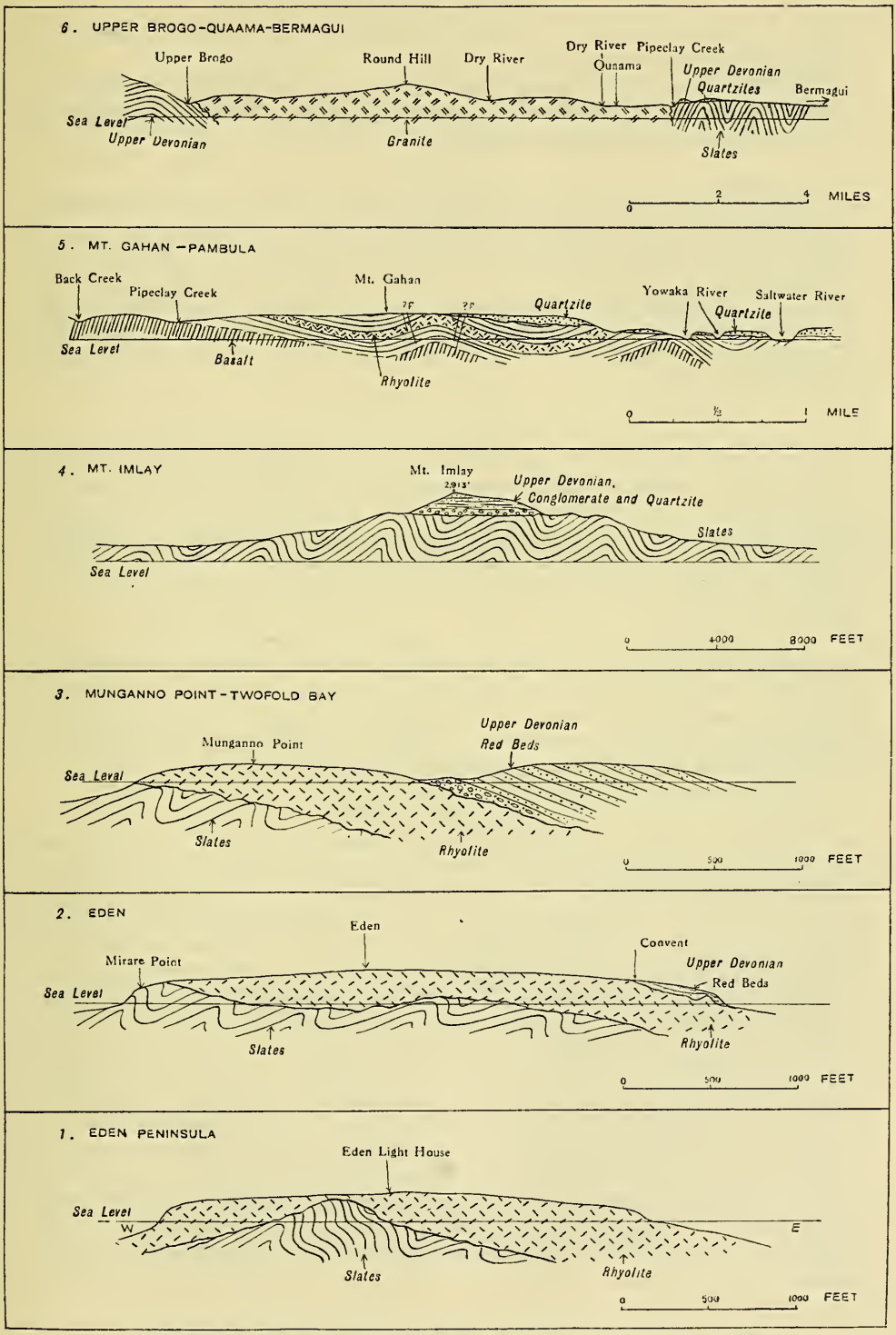
Granitic rocks extend a considerable distance to the west of Quaama, and near the head of the Brogo River (Portion 10, Parish of Mookerah, County of Auckland) they are in contact with purple sandstones and quartzites with interbedded red shales, similar to the Devonian beds of the Eden district. These sediments dip E.35°N. at 45°, and the intrusive granite appears to have worked its way along the bedding planes of the invaded sediments; there is clear evidence that the granite is later than Upper Devonian.

Rough inaccessible country separates the outcrop of this contact from that exposed at Yourie, some 10 miles north-west of Cobargo, where the granite again intrudes sediments having the lithological characters of the Upper Devonian.

A diagrammatic section from Upper Brogo to the east of Quaama is given in Text-figure 1, section 6.

(*b*) *Nerrigundah to Eurobodalla.*

Folded pre-Devonian rocks extend from the coast in the neighbourhood of Narooma, to Bodalla and Eurobodalla, on the Tuross River. West of Tuross Bridge at Eurobodalla are typical Upper Devonian sediments, purple quartzites and interbedded chocolate shales, which extend as far as Nerrigundah and form a ridge about 700 feet in height. These sediments are folded in a meridional direction, the dips amounting to about 25 degrees. West of Nerrigundah outliers of Devonian sediments form cappings to hills, which consist chiefly of the highly



Text-fig. 1.—Diagrammatic geological sections of the South Coast.

folded pre-Devonian series. Gold-bearing reefs occur in the older series, and these have been described by L. F. Harper (1923).

The Devonian beds are about 1,000 feet in thickness, and are lithologically similar to those of the upper stage at Eden. No interbedded igneous rocks are known to occur here (Text-fig. 2, section 1).

(*c*) *Wamban Creek.*

Quartz-porphyry or rhyolite occurs about seven miles south-west of Moruya, south of Wamban Creek, the general direction of strike being slightly west of north. This outcrop is possibly a continuation of the rhyolite occurring at the junction of Burra Creek and Deua River. About a quarter of a mile west of the porphyry is a conglomerate ridge bearing N.40°W. and S.40°E., which runs through the Little Sugarloaf and the Wamban Sugarloaf, and continues towards the Bendithera Track to the north. These rocks are lithologically similar to the Upper Devonian of the coast.

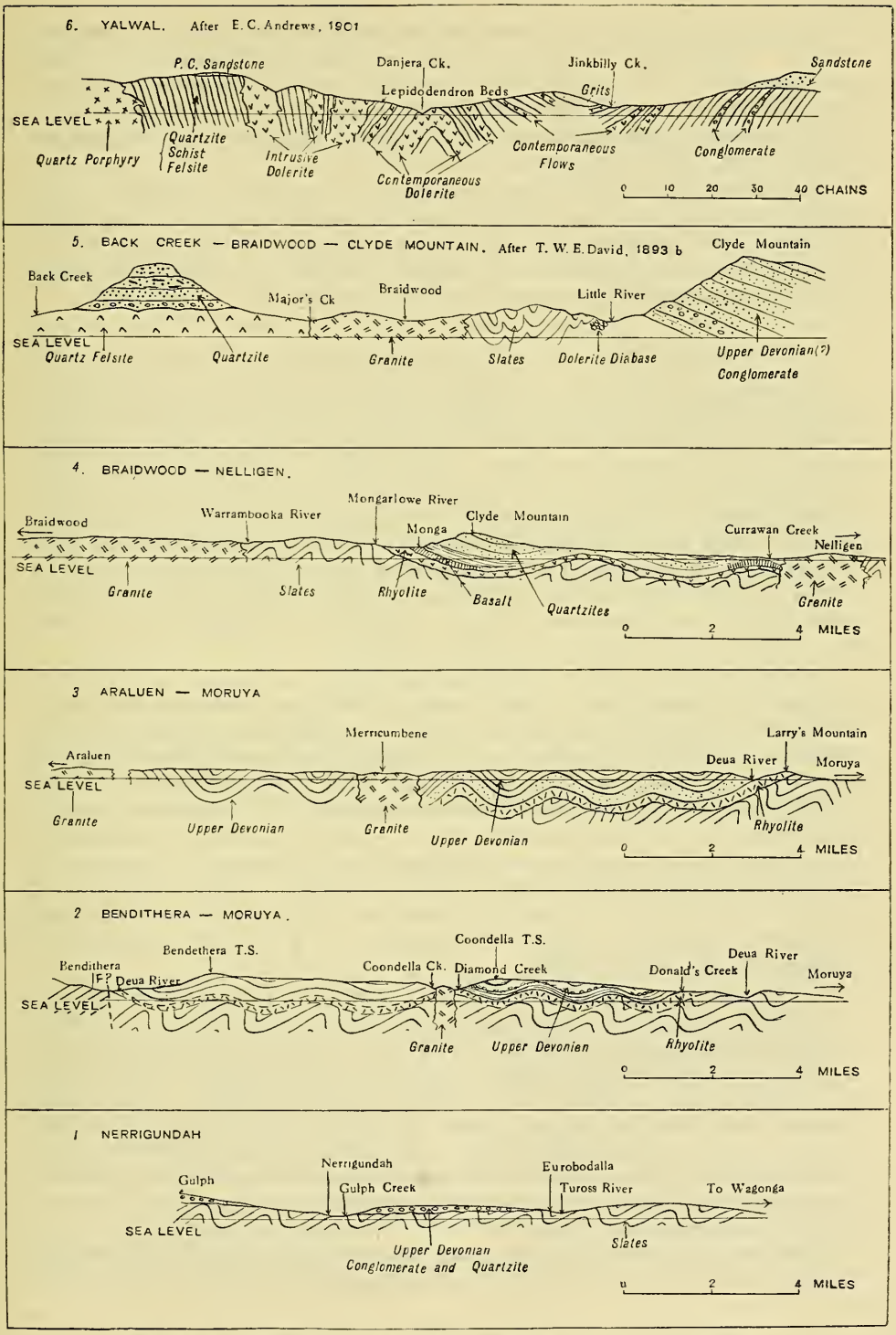
(*d*) *Section along the Bendithera Track, West of Moruya.*

The section from Moruya to Bendithera has been described in detail by the writer (1930). Devonian rocks outcrop between the junction of Burra Creek and the Deua River and Bendithera near the head of the Deua River. These beds overlie the rhyolite outcropping along the Araluen Road south of Larry's Crossing; they have been cut through by Diamond Creek, a southern tributary of Burra Creek, and possibly by the Upper Deua River at Bendithera, so that the basal (?) rhyolite is exposed.

The series is more strongly folded along this section than in the southern areas, the general trend of the fold axes being in a north-north-westerly direction. The rocks comprise conglomerates, quartzites and purple clay-slates; a thin bed of quartzite crowded with casts of *Spirifera disjuncta* outcrops south of Coondella Trigonometrical Station at an elevation of nearly 1,900 feet above sea level, and thus indicates an Upper Devonian age for the series (Text-fig. 2, section 2).

(*e*) *Deua River Section.*

The section along the Deua River was described by the writer in 1930, and its re-examination since the study of the Eden district confirms the previous suggestion that the sediments are of Upper Devonian age. It is now known, however, that the "porphyry" outcropping to the west of Moruya for several miles along the Deua River below Larry's Crossing is not intrusive, but takes the form of a series of flows over the surface of the older Palaeozoic schists which outcrop to the east. The western portion of the outcrop shows very distinct rhyolitic banding, especially in the slightly weathered rock, and the dip of the banding is in a westerly direction at 35 degrees, that is, approximately conformable with that of the overlying Upper Devonian sediments. The rhyolite is brecciated in places, a feature which may be due to movement of the lava under a partially consolidated crust, and is associated with tuffs on some horizons. The rhyolitic nature of the occurrence is confirmed in the field by its extension northwards, where it forms the upper portion of the range through the Wandera Mountain, west of the Buckemboura district. The field-relations therefore suggest its correlation with the Eden rhyolite and its lithological and chemical characters are strongly in favour of this supposition. The approximate thickness of the rhyolites and tuffs in this locality is about 700 to 800 feet. The lithological characters are described later, page 474.



Text-fig. 2.—Diagrammatic geological sections of the South Coast.

The overlying series of sediments has been described previously by the writer (1930). Lithologically the rocks bear very striking resemblances to the Upper Devonian rocks of the Eden district, and like them contain purple sandstones and quartzites with well-preserved ripple-marks as evidence of their shallow-water origin. A good example occurs near the 22 mile-peg from Moruya in beds that dip W.20°S. at 65° (Plate xxxi, fig. 3).

An important feature of this section is the high degree of folding of the sedimentary series as compared with that of the occurrences to the south. The direction of the fold-axes varies from north and south (magnetic) to N.20°W. and S.20°E., and the intensity of the folding increases as the granite batholith of the Araluen district is approached (Text-fig. 2, section 3).

(*f*) *Bateman's Bay to Braidwood via Monga.* Text-fig. 2, section 4.

The portion of the section from Bateman's Bay to the Clyde Mountain has been described previously by the writer (1930). West of the Clyde Mountain the road rises to a height of more than 2,500 feet above sea-level on the edge of the Main Divide, east of the village of Monga. It then runs in a northerly direction along the Mongarlowe River, a tributary of the Shoalhaven River, for six or seven miles before turning westwards to Braidwood. The granite of Araluen and Braidwood extends almost to the Mongarlowe River, where it is bounded by the older Palaeozoic series, consisting here of bluish-black slates dipping W.10° N. at 75°. A couple of miles to the south-east a hard bar of felsitic rhyolite, similar to that of Eden and the Lower Deua River, causes a waterfall in the Mongarlowe River. The flow structure in this rhyolite dips to the south-east.

At the village of Monga and along the river to the north, the rhyolite is overlain by a basaltic flow. A small quarry in the upper portion of the flow at Monga shows well-developed columnar structure; the rock is amygdaloidal, contains veins and amygdules of epidote, and is lithologically similar to the basalts of Nethercote and Pambula. The eroded upper surface of the basalt is exposed in the quarry and in the adjacent road-cutting, where it is overlain by about 10 feet thickness of red shales dipping south at 45 degrees, followed by interbedded purple quartzite and conglomerates containing rounded boulders of hardened red shales and purple quartzite, a typical Devonian sequence. Monga is about two miles west of the Clyde or Sugarloaf Mountain, where *Rhynchonella pleurodon* occurs in abundance in greenish-grey quartzite (T. W. E. David, 1893*a*; H. I. Jensen, 1908; W. S. Dun, 1930).

It is probably an extension of the basalt at Monga that has been described by H. I. Jensen (1908, pp. 57-58) as follows: "The basaltic mass which I examined in a valley near Sugarloaf Mountain is over half a mile wide and extends in a north and south direction for about ten miles. . . . The rock here termed basalt is a volcanic rock, in places quite vesicular and amygdaloidal." "The rock is certainly later than the Silurian schists and probably later than the Devonian, and may even be as late as the Tertiary, but its exact relations to the Devonian I have not yet worked out. The surrounding rocks are Devonian shales, quartzites and tuffs. They contain well preserved fossils, *Rhynchonella pleurodon*, *Spirifer disjuncta* and *Chonetes*."

This outcrop is indicated on the State geological map to the west of Budawong Mountain, and from its lithological character and field-associations there is little

doubt that it is a continuation of the Devonian basalt examined by the writer at Monga.

(*g*) *Major's Creek, near Braidwood.*

At Major's Creek, about ten miles to the west of Monga, Upper Devonian sediments rest on an eroded surface of quartz-felsite (Text-fig. 2, section 5); this occurrence was described by W. Anderson (1892), T. W. E. David (1893*a* and 1893*b*), and T. W. E. David and E. F. Pittman (1893). The latter authors write: "In July, 1892, Mr. T. P. Hammond, assistant to Mr. Geological Surveyor W. Anderson, discovered *Lepidodendron australe* in association with marine fossils, in rocks which are probably of Upper Devonian age on a hill overlooking Back Creek, about three miles from Major's Creek township. A number of other specimens of *L. australe* (some of them *in situ*) were subsequently discovered in this locality by Mr. W. Anderson and the authors. . . . The specimens are preserved as casts in ferruginous gritty sandstones, below which occur purple shales succeeded by marine grits and a basal conglomerate of quartz-felsite resting on an irregularly eroded surface of quartz-felsite."

Later (1893*b*) Professor David suggested the correlation of these Upper Devonian sediments with those of the Clyde Mountain and Mt. Lambie in New South Wales and with the Avon River sandstones and shales in Victoria. Of the underlying felsites he said: "The possibility suggests itself of this quartz-felsite being homotaxial with the Snowy River porphyries, which are probably of Lower Devonian age, according to A. W. Howitt and R. A. F. Murray."

(*h*) *Yalwal District.*

The Devonian rocks outcropping between Nelligen and Monga extend northwards and underlie the Permo-Carboniferous (Upper Marine) formation south of the Shoalhaven River. They are exposed by Ettrema and Yalwal Creeks, tributaries of the Shoalhaven, and have been described from Yalwal by E. C. Andrews (1901) as a series of folded sediments containing contemporaneous lavas (Text-fig. 2, section 6).

Mr. Andrews writes (p. 15): "The order of succession appears to be as follows: First a series of Devonian mudstones, sandstones and allied rocks were laid down.

"Intermittent periods of intense vulcanicity occurred at this period" during which immense rhyolite and basic flows were poured forth from various local centres.

"The higher members of the Devonian series consist of soft shales, grits and soft and hard tuffaceous material containing numerous *Lepidodendron* remains. With these are associated several sheets of very vesicular dolerite, numerous dolerite sills and smaller rhyolite flows."

No marine fossils have been found in the Yalwal series.

The rhyolites show conspicuous flow structure, and (p. 22) "a most interesting feature is the occurrence of large spherulites, varying in size from a pin's head to subspherical and ellipsoidal bodies two inches in diameter. The flow structure passes uninterruptedly through them. Concentric structure is plainly visible in some of the individual spherulites."

The dolerites are amygdaloidal, the amygdules containing "chloritic products, quartz, calcite and epidote" and the rock is traversed by "long strings of epidote and serpentine", a description which applies equally well to the basalts of Nethercote and Pambula, and with which they probably may be correlated.

It is interesting to note that (p. 22) "Copper . . . . has been found in one of the dolerite flows", an occurrence that is probably analogous to that described by H. I. Jensen (1908) from the basalt near Sugarloaf (Clyde) Mountain and Monga.

The *Lepidodendron* remains mentioned by Mr. Andrews have been described and identified by Dr. A. B. Walkom (1928) as *Protolepidodendron lineare*, n. sp., *P. Yalwalense*, n. sp., and *Lepidodendron* (?) *Clarkei*, n. sp. These plants are generally considered to be early forms, more primitive than the *Lepidodendron australe* of Major's Creek and Mt. Lambie.

To the north and west of Yalwal is a series of more arenaceous sediments (shown as "quartzites, and siliceous slates" on the map accompanying the Memoir of the Geological Survey, Geology, No. 7, by L. F. Harper (1915)) in which C. F. Laseron (1908, 1910) found Devonian marine fossils.

From the quartzites, sandstones and grits at the junction of Yalwal and Ettrema Creeks, Mr. W. S. Dun identified: *Allorisma* sp., *Sphenotus* sp., *Leptodomus* sp., *Pterinea* sp., and *Goniophora* sp., and from the Shoalhaven River, three miles west of Yalwal Creek: *Bellerophon* sp., *Euomphalus* ? sp., *Naticopsis* ? sp., *Mourlonea* ?, *Goniophora* ?, *Ctenodonta* sp., *Spirifera disjuncta*, and *Rhynchonella pleurodon*.

The relations between the Yalwal series and the Shoalhaven series of marine Devonian beds have not been observed, although C. F. Laseron (1908) gives some evidence in favour of the possibility that the marine beds overlie the Yalwal beds.

Petrology of the Volcanic Rocks.

Igneous rocks of probable Upper Devonian age on the South Coast may be grouped in three divisions: (1) Rhyolites occurring below Upper Devonian sediments; (2) rhyolites, rhyolite-breccias and felsites interbedded with Upper Devonian sediments; and (3) basaltic rocks partly intrusive into, and partly interbedded with Upper Devonian sediments.

(1). The first division comprises the lower volcanic stage of the Eden series, including the rhyolites of the Womboyne River, the rhyolite belt on both sides of Twofold Bay, the outcrops at Bournda Island, the coast near Tathra, Wandellow (?), the acid porphyritic rocks of the Lower Deua River, Diamond Creek (?), and the acid flows of the Mongarlowe River, north of Monga. Possibly the quartz-felsite of Major's Creek (T. W. E. David, 1893*b*, and W. Anderson, 1892) also belongs to this group.

The field occurrences have been described previously, where mention is made also of most of the macroscopic structures, such as columnar, nodular or spherulitic, and various types of fluidal structures in the rocks.

In the handspecimen the rocks vary in colour, texture and mineral constitution. The colour may be cream, light or dark grey or purple. The rocks are usually porphyritic; the phenocrysts are less than three millimetres in diameter, and are of quartz, or quartz and felspar; in some of the rocks of the Lower Deua River

the phenocrysts are very small and consist of orthoclase. The groundmass is lithoidal or felsitic.

Under the microscope the quartz phenocrysts show corrosion; the felspar is generally altered, but appears to be acid plagioclase as a rule; orthoclase has been noticed only in the Deua River rocks. The rhyolite from the quarry at "Edrom", Eden, shows pseudomorphs in chlorite and iron oxide apparently after a ferromagnesian mineral. The groundmass is devitrified, microcrystalline or hypohyaline. Frequently the fluidal fabric is indicated by streaks in the groundmass of varying crystallinity. Radiating spherulitic structure is present in some sections.

A section of one of the larger spherulites from Munganno Point shows concentrically arranged layers of flinty material, with slight radiating structure, through which the original flow-lines may sometimes be seen to pass. In the centre there is an amygdule of crystallized quartz, and the spherulite appears to be a secondary structure developed about the original geode at the expense of the rhyolite (Plate xxxii, fig. 2). The structure resembles that described in great detail by Cole (1886) and Parkinson (1898, 1901) as "pyromérides", and seems to be due to the replacement and growth of normal spherulitic structures by flinty material. On weathering, the surface of the outer layer exhibits an appearance similar to perlitic cracking in rhyolites.

Two analyses of rocks of this series have been made, and are given in Table I. The first is of the rhyolite from the quarry at "Edrom", Twofold Bay, which is typical of the rocks in this district; the second is of a banded rhyolite near the top of the rhyolite series outcropping along the Lower Deua River, west of Moruya.

The analyses quoted in Table I are very similar, being both those of normal potassic rhyolites, and as such show resemblances not only to those of Devonian age, but also to some described by H. C. Richards (1916) and H. C. Richards and W. H. Bryan (1924) of Permo-Carboniferous and even Tertiary age.

The excess of potash over soda is shown in the norm by the greater abundance of orthoclase than plagioclase, although this does not appear to be so in the mode. The felspar phenocrysts are usually plagioclase; anorthoclase is suspected in one rock (M. 960), and orthoclase occurs in some of the Deua River rocks. Apparently much of the potash occurs in the minerals of the groundmass.

The analyses are compared with those of three rocks from the Gippsland district of eastern Victoria, two being from the Wellington district and one from Mt. Tara Range, belonging to the Snowy River porphyry series.

The Mount Wellington rocks have been referred to by A. W. Howitt (1876–77), R. A. F. Murray (1877, pp. 44–57), E. W. Skeats (1909), E. O. Teale (1920), and others, and form part of a flow or series of flows between 1,000 and 2,000 feet in thickness at the base of sediments of probable Upper Devonian age. Thus they occupy a position analogous to that of the South Coast acid volcanic rocks. E. O. Teale (1920, p. 125) notes that "the porphyries and rhyolites of the Wellington Series form again a more acid series than those of the Snowy River". This is clearly seen by a comparison with the analysis in Column V of an acid porphyrite from Mt. Tara, in the Snowy River Series.

TABLE I.

	I	II	III	IV	V	VI	VII	VIII
SiO_2 ..	75·34	75·91	78·64	78·47	72·55	62·56	74·72	69·24
Al_2O_3 ..	11·89	11·89	9·85	10·68	11·74	16·60	13·05	12·88
Fe_2O_3 ..	1·54	1·58	0·54	0·18	2·54	1·02	0·52	0·20
FeO ..	1·60	0·96	2·00	2·23	0·46	5·98	1·42	4·05
MgO ..	0·28	0·47	0·10	tr.	0·68	2·71	0·41	2·21
CaO ..	0·16	0·26	0·80	0·66	1·85	4·30	0·66	3·10
Na_2O ..	2·06	2·23	2·03	3·29	3·46	2·98	3·62	2·94
K_2O ..	3·82	5·59	5·16	4·15	4·41	2·57	4·31	3·66
H_2O+ ..	1·18	0·58	0·40	0·2	0·41	0·68	0·61	0·80
H_2O- ..	0·16	0·09	0·14	0·09	0·06	0·18	0·13	0·06
CO_2 ..	1·60				1·80		0·08	
TiO_2 ..	0·31	0·28	0·67	0·59	0·175	1·10	0·16	0·04
P_2O_5 ..			tr.	tr.	0·14	0·17	0·38	abs.
MnO ..	tr.	tr.				tr.		0·06
Other Con.								0·82
	100·04	99·84	100·33	100·54	100·27	100·85	100·07	100·06

TABLE OF NORMS.

	I	II	III	IV	V	VI	VII
Quartz		40·68	44·70	40·98		18·48	35·58
Orthoclase		33·36	30·58	24·46		15·57	25·58
Albite		18·86	16·77	27·77		25·15	30·39
Anorthite		1·39	2·78	2·22		20·57	0·56
Corundum		1·63	—	—		1·33	2·24
Diopside		—	0·96	0·99		—	—
Hypersthene		0·10	2·05	2·51		15·12	2·85
Magnetite		2·32	0·70	0·23		1·39	0·70
Ilmenite		0·61	1·22	1·06		2·13	0·30
Apatite						0·34	0·93
Class		I	1	1		II	I
Order		3	3	3″		4	3
Rang		1	1	1″		3	1
Subrang		(2)3	2	3		(3)4	3
Magmatic Name.		Alaskose	Magdeburgose	Alaskose		Tonalose	Alaskose

I.—Rhyolite, Quarry, east of "Edrom", East Boyd, Twofold Bay. Anal. I.A.B.

II.—Rhyolite, Deua River, road to Araluen, 11 miles from Moruya. Anal. I.A.B.

III.—Banded Rhyolite, Southern Plateau of Wellington, Victoria. Anal. E. O. Thiele. *Proc. Roy. Soc. Vict.*, xxi, Part i, 1908, p. 266. Norm from Washington's Tables, p. 59.

IV.—Quartz-porphyry, southern shore of Lake Karng, Wellington district, Victoria. Anal. G. Ampt. *Proc. Roy. Soc. Vict.*, xxi, Part i, 1908, p. 266. Norm in Washington's Tables, p. 71.

V.—Quartz-porphyrite, No. 100, Mt. Tara Ranges, Snowy River Porphyry Series. Anal. E. O. Teale. *Proc. Roy. Soc. Vict.*, xxxii, Part ii, 1920, p. 125.

VI.—Dacite, Willimigongong Creek, near "Cheniston", Upper Macedon. Anal. Lewis and Hall. *Bull. Geol. Surv. Vict.*, No. 24, 1912, p. 17. Norm from Washington's Tables, p. 401.

VII.—Rhyolite, Blue Hills, Taggerty. Anal. E. S. Hills. *Proc. Roy. Soc. Vict.*, xli, Part ii, 1929, p. 189.

VIII.—Hypersthene-bearing quartz-porphyry, Burrenjuck, near Yass. Anal. J. C. H. Mingaye. *Ann. Rept. Mines Dept. N.S.W.*, 1907, p. 185.

These analyses may also be compared with that of a rhyolite from the Blue Hills, Taggerty, which also occurs near the base of Upper Devonian sediments, and has been described by E. S. Hills (1929).

The table of norms shows the similarity of the Deua River, Lake Karng and Taggerty rocks even more distinctly, and they all belong to the same subrang according to the C.I.P.W. classification.

On account of slight carbonation, the norms of the Eden rhyolite (Column I) and the quartz-porphyry from Mt. Tara Ranges (Column V) were not calculated.

The dacites of Mt. Macedon, a typical analysis of which is quoted in column VI, are described by E. W. Skeats (1909) and E. W. Skeats and H. S. Summers (1912) as probably equivalent to the Snowy River porphyries and of Lower Devonian age; the later work of E. S. Hills (1929) suggests that the Macedon dacites may be Upper Devonian. The rock is more basic than the South Coast series.

Similarly the porphyrite from Burrenjuck, whose analysis is quoted in Column VIII, shows resemblance to the South Coast rocks: it occurs between intrusive granite and the Middle Devonian rocks of the Murrumbidgee district, described by L. F. Harper (1909*a*).

(2). The second division consists of rhyolites, rhyolite breccias and felsitic rocks interbedded with sedimentary rocks of Upper Devonian age. The best exposures of these rocks in the Eden district occur to the west of Eden, through the Nethercote district and northwards to the Mt. Gahan Ridge and the Pambula to Wyndham road; the outcrops are indicated on Plate xxxiii. Similar rhyolites interbedded with Upper Devonian sediments have been described from Yalwal (E. C. Andrews, 1901).

The rhyolites and felsites of this stage differ from most of the rocks of the lower stage in having few or no phenocrysts. The rocks show little variation; they are very fine-grained and frequently show well-developed banding due to flow structure. Macroscopic and microscopic spherulitic structures also occur. Specimens of acid rocks belonging to this and the lower stage have been collected by the writer from about seventy different localities, and the Mining Museum, George Street North, Sydney, contains specimens from the Mt. Gahan Goldfield.

Under the microscope the rocks are seen to be devitrified, and the fluidal fabric is shown by variations in the grainsize of the different bands. The phenocrysts, which are seldom present, consist of either the acid plagioclase, oligoclase (M.960, M.359), or orthoclase, both of which are decomposed, and rarely quartz. The groundmass is very finely crystalline, frequently showing spherulitic structure (M.960, M.775). A section of an altered rhyolite from Mt. Gahan (M.749) shows well-developed perlitic fracture in ordinary light.

No chemical analyses of these rocks have been made; many of them look very similar to the rhyolite from the Deua River, whose analysis is given in Table I.

(3). Amygdaloidal basalts form the third group of Devonian igneous rocks. The chief outcrops occur west of Eden and in the Nethercote district, where at least two distinct flows occur to the east of Nethercote Model Farm. An extensive interbedded flow outcrops between Back Creek, a western tributary of Yowaka River, and Lochiel on the Pambula to Wyndham road, and continues to the "Six Mile" on the latter road. Other outcrops occur near the head of the Bald Hills Creek north of Pambula Trigonometrical Station, and west of the main road between the Saltwater Creek Bridge and the Mt. Gahan turn-off. These areas are shown on Plate xxxiii.

At Monga, south-east of Braidwood, a similar rock overlying the rhyolites is probably an extension of the outcrop described by H. I. Jensen (1908), and amygdaloidal basalts are interbedded with the Upper Devonian of the Yalwal series described by E. C. Andrews (1901).

The lower horizons of the basalt are more compact than those above, which are generally amygdaloidal, the amygdules consisting of epidote, calcite, chlorite and zeolites. Occasionally the rock is traversed by veins of fibrous asbestos and quartz, the asbestos fibres being at right angles to the length of the vein.

Under the microscope the rocks show some variations. They are all holocrystalline; the grainsize varies from very fine to medium; sometimes the rock is slightly porphyritic in plagioclase, and amygdaloidal structure is common. Most sections show at least a tendency to ophitic fabric, and one (M.808) is inclined to be variolitic.

Plagioclase occurs as idiomorphic laths, but rarely appears fresh. M.898 contains patches of fresh oligoclase, and other slides contain albite-oligoclase, but usually the felspar is albite, even in a fresh rock. Slides M.899 and M.900 show the complete replacement of plagioclase by epidote crystals, which are distinctly lighter in colour than the surrounding interstitial epidote. In one of the rocks analysed (M.938) there are a few phenocrysts of unaltered anorthoclase. The ferromagnesian mineral is colourless augite, allotriomorphic and interstitial; no fresh olivine has been observed, but pseudomorphs in serpentinous material and iron oxides indicate its former presence. Interstitial chloritic material is present in most sections, and vesicles contain calcite, epidote, chlorite and sometimes small quantities of a colourless radiating zeolite, with low double refraction, whose exact identity has not been determined.

The albitized nature of the felspars and the occurrence of calcite, epidote and alteration products in apparently fresh basalt are considered to be due to the action of deuteric agencies during the consolidation of the rock. The effects of this process are widely distributed and following the work of Bailey and Grabham (1909), Dewey and Flett (1911), A. K. Wells (1922–23), H. C. Sargent (1917) and others, albitization and kindred phenomena have been recognized in many rocks of all ages.

The occurrence of spilites in the Devonian rocks of the Tamworth district, described by W. N. Benson (1913, 1915*a*, 1915*b*, 1918) and in the Silverwood district of Queensland (Richards and Bryan, 1924) suggested the possibility of their occurrence among the Devonian rocks of the South Coast. However, a critical examination of the albitized basalts of the South Coast and a comparison with the published descriptions of spilitic rocks from Great Britain (H. Dewey and J. H. Flett, 1911, A. K. Wells, 1923), Eastern Fennoscandia (P. Eskola, 1925) and elsewhere indicates that the South Coast rocks are not true spilites, although they show some of their characteristics.

No pillow structure has been observed in the Nethercote basalts, although they are interbedded with red mudstones, and were formed in an area that was undergoing slow subsidence, and a change from freshwater to marine conditions. Like the spilites, they appear to be very altered, and the chief constituents are albitized plagioclase, augite and the remains of olivine, together with deuteric minerals (Sederholm, 1916).

Two analyses have been made of these rocks, one of relatively compact basalt, the other of a slightly amygdaloidal type. Since the minerals of the amygdules are regarded as essential magmatic products, they were not separated from the basalt, but were included in the rock analysed.

TABLE II.

	I	II	III	IV	V	VI	VII
SiO_2	46·28	49·87	54·10	49·35	51·14	48·22	53·41
Al_2O_3	16·02	15·91	16·45	17·61	14·47	14·82	11·58
Fe_2O_3	2·43	3·55	4·04	1·50	3·60	0·56	0·97
FeO	7·27	10·09	6·49	9·72	8·28	9·25	9·90
MgO	6·84	4·84	3·69	3·17	5·80	5·58	2·59
CaO	8·86	8·27	6·16	7·71	9·64	8·81	7·81
Na_2O	2·83	2·17	4·97	3·10	2·43	4·95	4·90
K_2O	0·25	1·10	1·01	1·56	0·57	0·44	0·82
H_2O+	3·65	2·44	1·01	2·56	2·52	2·54	} 3·29
H_2O-	0·30	0·19	0·16	0·65	0·34	0·15	
CO_2	2·58	0·22	0·75	—	—	1·40	1·19
TiO_2	1·94	1·89	1·22	2·83	0·75	2·68	3·13
P_2O_5	0·34		0·26	tr.	0·08	0·23	0·36
MnO	0·11	pr	0·26	0·07	0·22	0·23	0·18
Other Const.				0·34	0·03	0·40	0·05
	99·70	100·54	100·37	100·17	99·87	100·26	99·78

TABLE OF NORMS.

	I	II
Quartz	1·08	4·92
Orthoclase	1·11	6·67
Albite	24·10	18·34
Anorthite	25·58	30·30
Corundum	1·73	—
Diopside	—	7·82
Hypersthene	25·42	20·63
Magnetite	3·48	5·10
Ilmenite	3·65	3·65
Apatite	0·67	—
Calcite	5·90	0·50
Class	"III	(II) III
Order	5	5
Rang	4	4
Subrang	4–5	4–5
Magmatic Name	Auvergnose	Auvergnose

I.—Amygdaloidal Basalt, east of Nethercote, Eden district, N.S.W. Anal. I.A.B.

II.—Compact Basalt, portion 68, Parish of Eden. Anal. I.A.B.

III.—Andesite (Spilite), Elbow Valley, Silverwood, Queensland. (Anal. ?). *Proc. Roy. Soc. Queensland,* 1924, xxxvi, No. 6, p. 88.

IV.—Melaphyre, Moroka Snow Plain, Victoria. Anal. G. Ampt. *Proc. Roy. Soc. Vict.,* xxxii, Part ii, 1920, p. 98.

V.—Albitic Dolerite, Loomberah, Tamworth district, N.S.W. Anal. J. C. H. Mingaye. Proc. Linn. Soc. N.S.W., xliii, 1918, p. 368.

VI.—Spilite, Frenchman's Spur, Nundle. Anal. W. N. Benson. Proc. Linn. Soc. N.S.W., xl, 1915, p. 139.

VII.—Ophitic Albite-Clinopyroxene rock. Spilitic lava bed in the Solomen Breccia, Solomen, western shore of Lake Onega. Anal. P. Eskola. *Fennia,* 45, No. 19, 1915.

The two analyses show variations compatible with mineralogical differences; the relatively greater abundance of chlorite, epidote and calcite accounts for the higher percentages of water and carbon dioxide in the amygdaloidal basalt. The analysis of a melaphyre from Moroka Snow Plain in the Mount Wellington district of Victoria, quoted in column IV, shows close resemblance to the Eden rocks, a feature which is interesting in view of their similar field associations and probable ages.

Compared with the two analyses of spilitic rocks quoted in columns VI and VII, the Eden rocks differ in exactly those respects which specially characterize the spilites. Although soda is dominant over potash, the alkalis are not particularly high, and the alumina of the Eden rocks is comparable to that of normal basalts, whereas the spilites are somewhat deficient in alumina. It is therefore evident that the Eden rocks are not true spilites, although they show some resemblances to rocks such as the albite-dolerite, whose analysis is quoted in column V, that are associated with the spilites.

There is also a general resemblance to the rock whose analysis is quoted in column III, which is regarded by H. C. Richards and W. H. Bryan (1924) as spilitic. This similarity is interesting as the rock is associated with spherulitic rhyolites of the Devonian series at Silverwood, Queensland.

The Age of the Basal Rhyolites.

The only direct evidence of the age of the igneous flows of the lower stage is that they overlie sediments of Silurian or Ordovician age with a marked unconformity, and underlie Upper Devonian sediments with a slight unconformity, indicated mainly by an erosional break. The general trend and dip of the igneous flows are approximately conformable with those of the overlying beds, suggesting that although erosion and probably vertical movement took place before the deposition of the red beds, the unconformity does not necessarily indicate a long time-interval between the two formations, say equivalent to that of the Middle Devonian Epoch, when enormously thick deposits of shales, limestones and tuffs were deposited in the Murrumbidgee area (L. F. Harper, 1909*a*). So far as the writer is aware there are no Middle Devonian sediments on the South Coast.

In the adjacent district in Victoria the Lower Devonian is represented by the Snowy River Porphyries, which are partly overlain by Middle Devonian sediments, as described by A. W. Howitt (1875), E. O. Teale (1920), and others. The dacites and quartz-porphyrites of Mt. Macedon (Skeats and Summers, 1912) and the Dandenong Hills, and the series of alkaline rocks of Mt. Leinster; Frenchman's Hill, Omeo; and Mt. Elizabeth, Noyang, have all been regarded as probably Lower Devonian (E. W. Skeats, 1909; T. W. E. David and E. W. Skeats, 1914, p. 305),

but the recent discovery by E. S. Hills (1929) may modify these correlations. Mr. Hills discovered fish remains of a typically Upper Devonian aspect in sediments underlying rhyolites that were "formerly believed to be Lower Devonian dacites". This important discovery "necessitates a revision of our conception of the age of the other Victorian dacites, and those that can be linked petrographically with the Marysville rocks must also be placed in the Upper Devonian".

An extensive flow of rhyolite occurs at the base of the Mt. Wellington series, and is chemically similar to the acid igneous rocks of the South Coast, with which it has been compared, page 475. E. O. Teale (1920, p. 125) calls attention to the fact that the rock is more acid than the Snowy River porphyries, and implies that petrological distinctions may be made. Teale regards the sedimentary series as Lower Carboniferous, but the Geological Survey map (1909) shows it as Devonian.

The Snowy River porphyries were considered by A. W. Howitt (1876-7) to be due to the activity of a line of volcanoes running approximately in a meridional direction near the course of the Snowy River. The distribution of the later Middle Devonian rocks both in Victoria and in New South Wales suggests that the occurrence of the Snowy River porphyries had a tectonic significance, foreshadowing the position of subsequent geosynclinal deposition during Middle Devonian time.

Since no Middle Devonian sediments occur above the lower igneous series of the South Coast, which might have been heralded by igneous activity, and since the series is comparable petrologically, chemically, and stratigraphically with the rhyolites of Mt. Wellington and probably those of Taggerty-Marysville, it is considered by the writer that these groups may be correlated, and that the Eden series and its equivalents along the South Coast may be regarded as the lowest stage of the Upper Devonian rocks on the South Coast of New South Wales.

Correlation of the Devonian Rocks of the South Coast.

From the descriptions in the preceding pages it is evident that outcrops of Upper Devonian rocks occur at a number of localities along the South Coast between the Shoalhaven River and the Victorian Border. Reference to the accompanying map (Plate xxxiv) indicates that the formations were deposited in a relatively narrow synclinal trough, whose axis was situated inland from the present coast-line. Subsequent earth movements produced folding of the sediments, the axes of the folds being approximately parallel to the trend of the structural depression in which the sediments were deposited. The arcuate character of the trough, which is emphasized by the arrangement of the trend lines, as shown on the map between Eden and Yalwal, suggests that a massif of older rocks existed to the east, which may have been portion of the Tasmantis of Süssmilch and David (1919, p. 277).

The Devonian rocks, which all belong to the Upper series, rest with a marked unconformity on a highly folded series of Pre-Devonian schists, phyllites and slates. The sediments contain plant remains and a marine fauna, which are typically Upper Devonian, and evidence has been produced in the previous pages to show that the underlying volcanic rocks are also probably of Upper Devonian age.

The most complete sequence occurs in the Eden district, where three stages of Upper Devonian series have been recognized, (i) a lower volcanic stage,

possibly of terrestrial origin, (ii) a middle stage of sediments and contemporaneous volcanic rocks, and (iii) an upper stage of marine, arenaceous sediments.

These three stages may be recognized at intervals along the South Coast, although the entire sequence is not always represented. The diagrammatic columnar sections (Text-fig. 3) of the areas previously described, illustrate the writer's opinion of the age relationships of the formations under consideration.

(i). It is proposed to call the lower volcanic stage the *Eden Stage* on account of its typical development in the vicinity of Eden. The distribution of the Eden stage is more limited than that of the succeeding stages; it outcrops at intervals along both sides of the zone of Upper Devonian sedimentation, occurring on the western side of the red beds south of Twofold Bay, and under the sediments of the Eden district; at Monga the basal Devonian rhyolite dips towards the east under the quartzites of the Clyde Mountain; and the quartz-felsite of Major's Creek, described by Professor David (1893*b*) is possibly a western extension of this occurrence. The quartz-porphyry indicated north-west of Yalwal on the map by Mr. Andrews (1901) may possibly represent the Eden stage. Along the eastern border of the Devonian trough the Eden stage is well developed in the neighbourhood of the Wandera Mountain, west of Buckemboura, and along the Lower Deua River and its tributaries.

Again at Tathra, east of Bega, and along the coast as far south as Bournda Island, the outcrops of "porphyry" and rhyolite are to be correlated with the lower or Eden stage. The maximum thickness of this stage varies from 450 feet in the Eden district to 800 feet along the Lower Deua River.

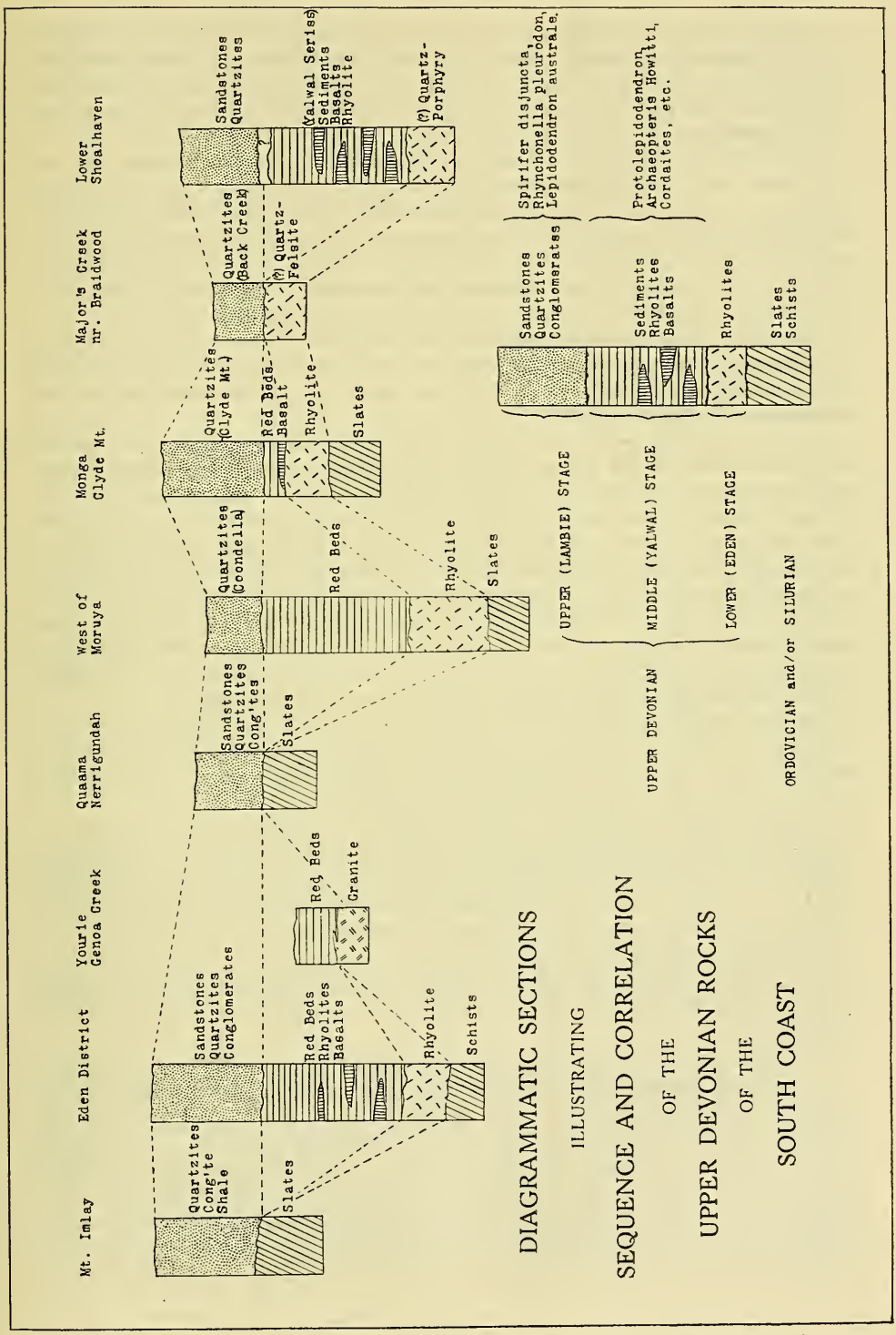
(ii). It has been shown that in the Eden district the middle stage is deposited over the eroded surface of the lower stage, and consists of a great development of red beds, with contemporaneous basalts, rhyolites and felsites. On account of the striking lithological resemblances to the series described by Mr. Andrews from Yalwal, confirmed by the occurrence of *Protolepidodendron* in the Eden and Yalwal beds, it is considered that the rocks are of similar age.

In the Eden district the middle stage attains a thickness of 1,500 feet and dips more or less conformably with the underlying igneous flows. Igneous action continued during the deposition of the red beds and produced interbedded flows of rhyolite, felsite and basalt. The red beds themselves may be of tuffaceous origin. The occurrence of basalts, related in some respects to the spilites, may be significant of the general movement of subsidence, which produced the marine transgression of the following stage.

The most extensive outcrops of the middle stage occur along the coast from Disaster Bay to the north of Merrimbula and inland through the Nethercote district.

Lithological similarities and the occurrence of Upper Devonian plant remains (*Cordaites*?) suggest the correlation of the Upper Genoa Creek beds and the middle stage of the Eden series.

Red beds of the middle stage occur in the Upper Brogo River and at Yourie, as well as along the Deua River Valley below Araluen. The thin series of red beds and basalts near Monga, occurring between the basal rhyolites and the Clyde Mountain sediments are considered to belong to the Yalwal stage, but evidently it thins out entirely before reaching Major's Creek, according to the section given by Professor David (1893*b*), (see Text-fig. 2, section 5).



Text-fig. 3.—Columnar sections illustrating sequence and correlation of the Upper Devonian formations of the South Coast.

Yalwal may be considered as the type locality for the rocks of this stage, and it is proposed to designate this the *Yalwal Stage*, defining the term to include the freshwater sediments, characterized by the presence of *Protolepidodendron*, *Archaeopteris Howitti*, *Cordaites*, and similar plant remains, together with contemporaneous lava flows.

(iii). Rocks that are lithologically equivalent to the Upper Stage of the Eden series have a more widespread distribution on the South Coast than either of the lower stages, since they overlap their outcrops and frequently rest directly and unconformably on pre-Devonian sediments. They consist essentially of conglomerates, grits, quartzites and mudstones of shallow water origin, and occasionally contain typical Upper Devonian marine fossils. No definite evidence of igneous action has been recognized in this stage on the South Coast.

Reference to the accompanying maps and sections shows that at Mount Imlay and along the ridge north of the Nullica River the Upper Stage rests on pre-Devonian formations, and similar relations occur east of Quaama and in the neighbourhood of Nerrigundah.

Along the Bendithera, Deua River and Clyde Mountain sections the marine beds overlie those of the middle (Yalwal) stage, but to the west of Monga, near Major's Creek, the middle stage is not represented and the marine stage rests on the quartz-felsite of the lower (Eden) stage. In the Shoalhaven district to the north there is a series of grits and quartzites from which a variety of Upper Devonian marine fossils, including *Spirifera disjuncta* and *Rhynchonella pleurodon*, has been collected by C. F. Laseron (1908). The exact field relations of these marine beds to the Yalwal beds have not been observed, but the lithological and palaeontological evidence strongly supports their correlation with the Upper and Middle Stages respectively, of the Eden district, thus placing the Devonian marine beds of the Shoalhaven River stratigraphically above the Yalwal beds.

In New South Wales the sediments outcropping at Mt. Lambie have been regarded as typical of the Upper Devonian of the south-eastern province (W. N. Benson, 1922). Compared with the Upper Devonian of the South Coast, it appears that only the Upper or Marine Stage is represented at Mt. Lambie.

As the origin, distribution, palaeontology and lithology of this stage are characteristic and distinct from those of the Eden and Yalwal stages, it is proposed to call it the *Lambie Stage*, understanding the term to apply not only to the sediments at Mt. Lambie, but to the whole of the marine stage of the Upper Devonian, which is stratigraphically above the Yalwal or middle stage of the Eden series.

The Lambie Stage is characterized by the presence of conglomerates, grits, quartzites and mudstones, in which a variety of marine forms is preserved. Typical fossils include *Spirifera disjuncta*, *Rhynchonella pleurodon* and *Lepidodendron australe*.

A review of the literature on the Upper Devonian rocks of New South Wales and Victoria suggests that the threefold division of the Upper Devonian series recognized on the South Coast may have more general application. Thus to the north of Yalwal, at Yerranderie, in the Upper Burragorang Valley, L. F. Harper (1930) shows (in section) the occurrence of a Devonian series of interbedded sediments and volcanic rocks underlying sediments containing Upper Devonian marine fossils. Upper Devonian sediments extend intermittently through the Kowmung Valley towards Hartley, Mt. Lambie, Capertee and Mudgee. Although the recorded Upper Devonian rocks of Mt. Lambie are chiefly marine sediments,

volcanic rocks occur immediately to the west, and may underlie the Lambie beds. This sequence is being investigated by the writer and Miss G. Joplin, B.Sc. From the Upper Macquarie Valley L. F. Harper (1909*b*) has described a series of Devonian rocks consisting of tuffs and contemporaneous lava flows of augite-andesite, felsite and rhyolite occurring beneath conglomerates, massive quartzites and sandstones containing *Rhynchonella pleurodon* and *Spirifera disjuncta*, a sequence which corresponds to that developed on the South Coast.

Maps of the Capertee district by J. E. Carne (1903) show a series of apparently unfossiliferous slates and sandstones separated by a belt of quartz-porphyry from a series of slates, sandstones and limestones from which a collection of Middle Devonian fossils was obtained (Carne, 1903, p. 125).

The whole series is regarded as Devonian and the occurrence of boulders containing *Spirifera disjuncta* in the overlying Permo-Carboniferous conglomerate indicates the existence of the Upper Stage of the Upper Devonian in the vicinity. The field relations of the quartz-porphyry to the Middle Devonian sediments on the one side and Upper Devonian (?) sediments on the other side are not definitely known, but the possibility of their analogy to the early Upper Devonian flows of the South Coast should be considered in future work in the district.

Records of the Devonian rocks of the Mudgee district include references to "andesites and rhyolites" (Benson, 1922, p. 103) which may correspond to the early Upper Devonian of South Coast. To the west of these areas the Devonian rocks consist mainly of arenaceous marine sediments of late Upper Devonian age.

In the adjacent areas in Victoria there are formations which appear to be analogous to the Upper Devonian rocks of the Eden district. These occur at Mt. Tambo, the Bemm River, Tabberabbera, Iguana Creek, and through the Mount Wellington and Mansfield districts, and have been described by a number of Victorian geologists including A. W. Howitt (1874-7), R. A. F. Murray (1877), E. O. Teale (1920), E. W. Skeats (1929), and many others. Palaeontological evidence of the age of these rocks is confined to fish and plant remains, and there appears to be no consensus of opinion regarding their age. This problem has been discussed recently by Professor Skeats (1929).

On the Geological Map of Victoria (1912) the beds round Mansfield are coloured as Carboniferous, and those to the south-east, surrounding Tamboritha and Wellington Mountains through to the head of the Avon River, Iguana Creek and the Tabberabbera districts are shown as Devonian.

The writer would tentatively correlate with the Lower (Eden) Stage of the Upper Devonian, the rhyolite of Lake Karng (Thiele, 1908, 1920) at the base of the Mt. Wellington series, and the rhyolites of the Taggerty-Marysville district (Hills, 1929*a*, 1929*b*), together with analogous volcanic rocks in Victoria.

The Middle Stage appears to be represented by the red and chocolate-coloured shales and sandstones of Iguana Creek, which contain *Cordaites australis* and *Archaeopteris Howitti*, and at Mt. Wellington and Snowy Bluff similar rocks are interbedded with rhyolites, felsites and basalts that are lithologically and chemically equivalent to those of the middle stage of the Upper Devonian at Eden. Probably at least portion of the Upper Devonian at Tabberabbera, described by Professor Skeats (1929), may be correlated with this stage.

A section through the lower part of the Upper Devonian at the Mitchell River, above Horseshoe Bend, is described as consisting of 350 feet of red and purple mudstones with thin bands of breccia and conglomerate and two flows of spherulitic rhyolite, followed by 70 feet of conglomerate and 500 feet of sand-

stone. The presence of melaphyre or altered basalt is suspected from boulders in the Mitchell River, but these have not been found *in situ*. Red mudstone, rhyolite-breccia and other specimens from this series, kindly lent to the writer by Professor Skeats, are remarkably similar to the South Coast rocks.

Similar red beds outcrop at Valencia Creek and Freestone Creek.

The Mansfield series of arenaceous sediments were classed by McCoy as the top of the Upper Devonian on the evidence of *Lepidodendron Mansfieldense* and a fossil fish. Later A. S. Woodward (1906) described the fossil fish as Carboniferous, and his classification is adopted by the Geological Survey. Professor Skeats (1929) points out that the absence of contemporaneous lavas in the sediments of the Mansfield region, as contrasted with the proved Upper Devonian beds of Victoria, may be regarded as evidence in favour of their possible Carboniferous age. It may be noted, however, that the upper stage of the Eden series is also devoid of igneous flows.

Lepidodendron australe, which was named and described by F. McCoy in 1874, was discovered in sandstones near the junction of Valencia Creek and the Avon River (Chapman, 1914). Regarding the stratigraphical horizon of the original specimen, R. A. F. Murray (1887) writes: "Professor McCoy expresses a strong opinion as to the Lower Carboniferous aspect of this fossil plant impression; and from my own observations I am inclined to believe that the beds in which it is found are among the uppermost of the group, and younger than, though conformable with, the Upper Devonian Beds of Freestone and Iguana Creeks." Since then *Lepidodendron australe* has been found at four other localities in the Macallister basin by E. O. Teale (1920), who tentatively regarded the Mt. Wellington beds as Lower Carboniferous, as they had not been distinguished from the Mansfield formation. In New South Wales *Lepidodendron australe* occurs in association with marine Upper Devonian fossils at a number of localities, as recorded by David and Pittman (1893), and its occurrence does not imply a Carboniferous age.

The Upper Devonian beds of Perry, South-eastern Maine, contain a form *Leptophloeum rhombicum*, which D. White (1905, pp. 72-73) regards as equivalent to *Lepidodendron nothum* Feistmantel and *Lepidodendron australe* McCoy.

The evidence of the Upper Devonian of the South Coast of New South Wales naturally suggests that similar conditions of sedimentation prevailed in the adjacent district of Victoria, and that two stages of sedimentation are represented here also, the lower (Yalwal) stage containing only remnants of a primitive land flora, being of lacustrine or estuarine origin and including interbedded acid and basic lava flows; and the upper (Lambie) stage consisting of arenaceous marine sediments, without evidence of igneous activity.

Tectonic History and Palaeogeography.

The examination of the Devonian rocks of the South Coast and their comparison and correlation with other Devonian formations in south-eastern Australia has led to a consideration of the general problem of the palaeogeography and geological history of this portion of the continent during Devonian time.

Professor W. N. Benson (1922, 1923) has already given a comprehensive account of Devonian sedimentation and tectonic structure, based on his own extensive researches and a careful survey of the previous literature, notably the work of W. B. Clarke (1860–1878), T. W. E. David (1893*a*, 1911, 1914), H. I. Jensen (1911), E. C. Andrews (1914, 1916*b*, 1922), and many others to whom reference is made.

The additional Devonian occurrences described in the present paper give evidence for an elaboration of the known stratigraphical succession of Upper Devonian rocks, and provide a means of more direct correlation of some of the known deposits in south-eastern Australia.

After the deposition of Ordovician and Silurian sediments, violent earth-movements affected the greater part of south-eastern Australia and the rocks were intensely folded. The axes of folding usually run in a meridional direction in New South Wales and in eastern Gippsland, Victoria, but in the western part of Gippsland the trend is more to the north-west. The Devonian formations usually rest with a marked unconformity on the eroded surface of the older formations.

In the Walhalla-Wood's Point district in Victoria, however, the Centennial beds contain evidence of continued sedimentation from Silurian into early Devonian time, as shown by the work of E. W. Skeats (1928) and W. Lang and I. Cookson (1930). Similar relations may obtain between the Silurian and Devonian at Bowning in the Yass district, New South Wales, according to J. Mitchell and W. S. Dun (1920).

Otherwise Lower Devonian unconformably overlie the Silurian and older rocks and are represented only by igneous rocks, typically the Snowy River porphyries. The dacites of Mt. Macedon (Skeats, 1909; Skeats and Summers, 1912) and elsewhere in Victoria have been regarded as Lower Devonian, but the recent discovery by E. S. Hills (1929) of Upper Devonian fish remains in sediments below rhyolites "formerly believed to be Lower Devonian dacites" casts some doubt on the age of analogous rocks. In New South Wales the volcanic series of Murrumbidgee (Harper, 1909; Shearsby, 1905) are considered to be Lower Devonian.

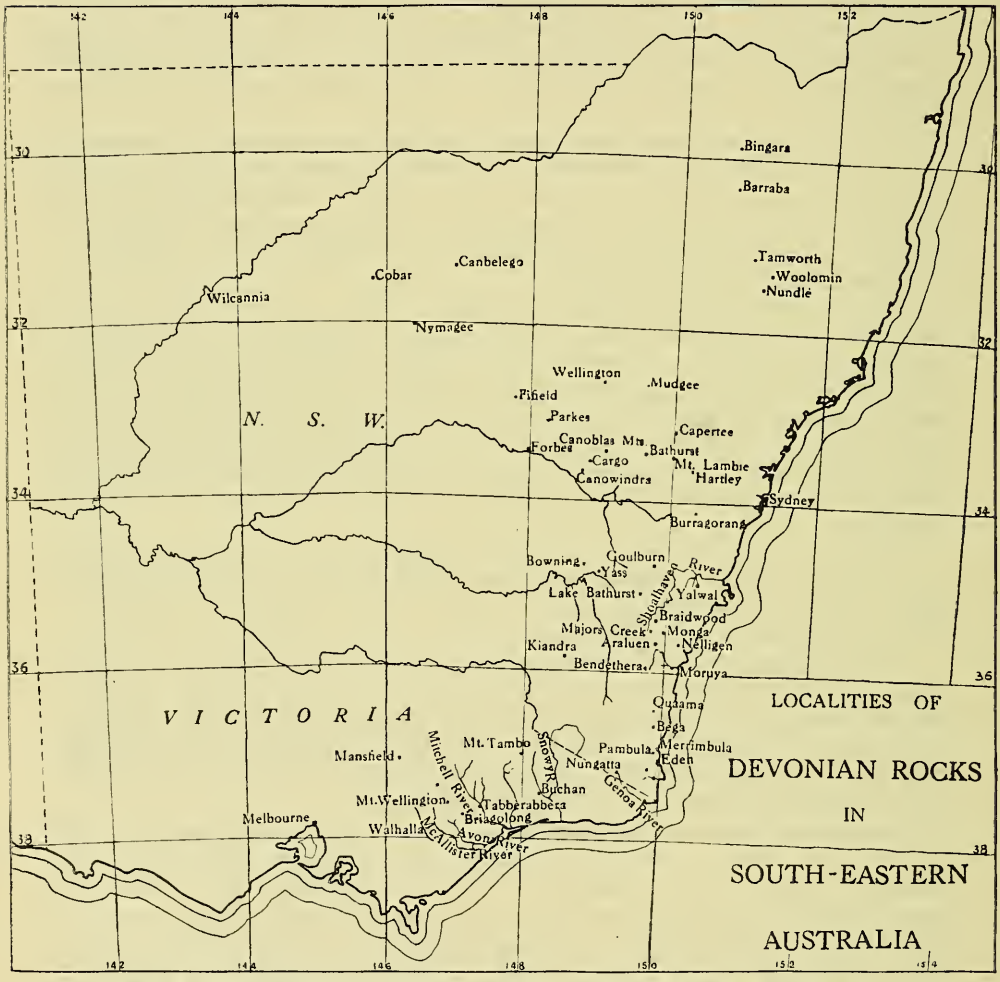
The sketch map (Text-fig. 4) shows the distribution of the known outcrops of Devonian rocks in Victoria and New South Wales, the information being taken from the State geological maps of 1909 and 1914 respectively, modified by reports subsequent to their publication.

The distribution of the Lower Devonian volcanic series appears to have a tectonic significance, probably being related to the trough-faulting and down-warping that produced the narrow gulf in which the Middle Devonian sediments were deposited. This gulf extended in a northerly direction from Victoria into New South Wales, including the areas of Buchan, Bindi, Tabberabbera, Limestone Creek, Lobb's Hole, and the Murrumbidgee, near Yass.

The Middle Devonian beds consist of shales, massive limestones, tuffs and acid volcanic rocks. At Buchan the series rests in hollows eroded out of the underlying Snowy River Porphyries. In the Murrumbidgee basin a rich and varied fauna has been preserved, more than a hundred forms being recorded by W. N. Benson (1922, pp. 95–96). Mr. Dun suggests (E. C. Andrews, 1916*b*, p. 757) that detailed examination of the fossils of the Murrumbidgee beds may show that Lower Devonian beds pass up into Middle Devonian, the whole series attaining a thickness of 14,000 feet, according to L. F. Harper (1909*a*).

There is some uncertainty as to the limits of the Middle Devonian gulf in New South Wales. Other Devonian limestones are recorded from many localities by Carne and Jones (1919), but no further details of their stratigraphical position are given, as palaeontological evidence of their age is scarce. These limestones occur in two main areas, one being the belt from Mudgee to near Capertee, and the other being in the neighbourhood of Goulburn and Tarago.

The Devonian rocks of the Capertee district were described and mapped by J. E. Carne in 1903. An assemblage of typical Middle Devonian fossils was obtained from the limestone at the Blue Rocks (Carne, 1903, p. 125), but the existence of Upper Devonian beds in the locality is indicated by the presence of *Spirifera disjuncta* in boulders in the overlying Permo-Carboniferous conglomerate, although the form has not been found *in situ*.



Text-fig. 4.—Sketch map of south-eastern Australia, showing localities of fossiliferous Devonian outcrops.

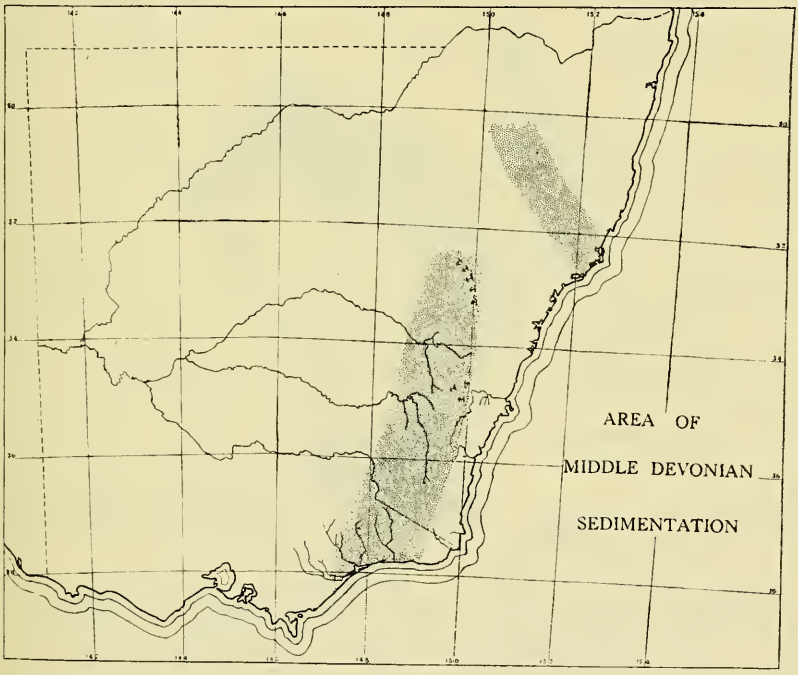
This area is therefore one of exceptional interest, for it seems probable that the relations between the Middle and Upper Devonian may be revealed in this locality.

The limestones of the Goulburn-Tarago district have been classed as Devonian mainly by their lithological associations; the only fossils known are from the outcrops west of Lake Bathurst Railway Station, described by J. E. Carne and L. J.

Jones (1919, pp. 136–137). From these beds Mr. Dun has identified *Receptaculites*, *Cyrtoceras*, dendroid *Favosites* and (?) Coral, which again have a Murrumbidgean aspect, although Upper Devonian sediments are known to occur in the vicinity.

There appears to be no authentic record of massive coralline limestone in the Upper Devonian of New South Wales, at least south or west of the Permo-Carboniferous basin. Some of the New England limestones are classed as Upper Devonian by W. S. Dun (1914, p. 292), but these are included in the Tamworth series of Middle Devonian by W. N. Benson (1922).

Otherwise Upper Devonian sediments are typically arenaceous, and the probability of conditions suitable for the growth of corals seems remote. The available evidence therefore indicates that the massive Devonian limestones of the Mudgee-Capertee and Goulburn-Tarago districts are Middle Devonian, and were formed in part of the Murrumbidgean gulf. The strike directions of these rocks shown on the map (Text-fig. 5) are taken from the published records of Carne and Jones (1919).



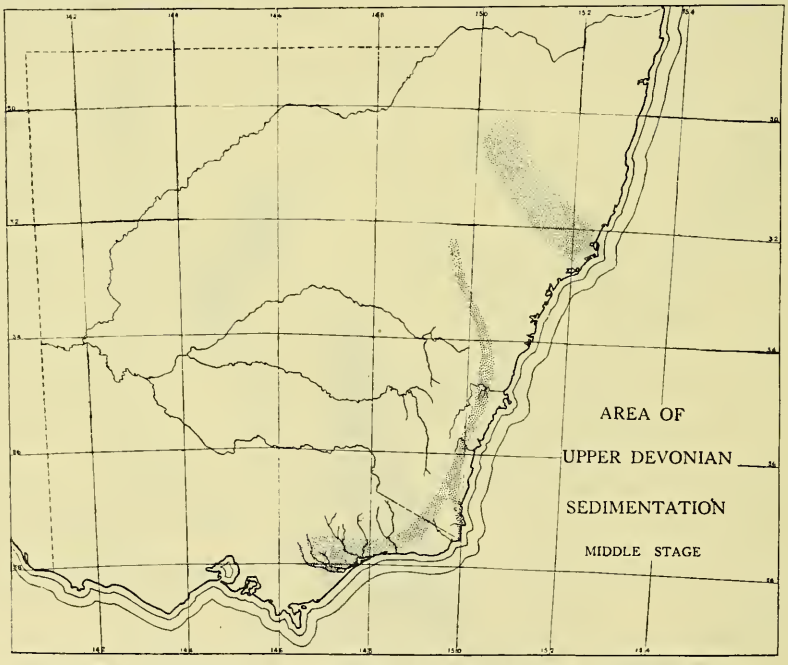
Text-fig. 5.—Sketch map of south-eastern Australia, showing area of Middle Devonian Sedimentation.

The distribution of the outcrops of Upper Devonian sediments (Text-figs. 6, 7) and the more intense folding of the Middle as compared with the Upper Devonian beds, indicates that the Murrumbidgean geosyncline suffered compression from the east at the close of the Middle Devonian, when the greater part of the former gulf was converted into dry land, most of which was not covered by the Upper Devonian sea.

This closing Middle Devonian orogeny is of considerable importance, inasmuch as it finally welded on the eastern massif to the growing Australian continent, and marked the close of an era of general compressive force from the east

indicated by the pronounced meridional trend of the Lower Palaeozoic rocks of south-eastern Australia. The trend-lines of the newer formations show progressive change from the meridional direction to north-north-west and north-west, the initial variation commencing in the Upper Devonian epoch. The strong unconformity between the Middle and Upper Devonian exposed by the Mitchell River below Tabberabbera (Skeats, 1929) is additional evidence of late Middle Devonian diastrophism.

The Upper Devonian commenced with an outburst of volcanic activity represented by extensive rhyolitic flows of the Eden Stage along a zone nearer the present coastline of south-eastern Australia than the former area of Middle Devonian deposition. These volcanic rocks may be traced from Mt. Wellington, Victoria, along the coast of New South Wales from Disaster Bay to Yalwal, thence inland through Burragorang, west of Mt. Lambie, and towards Capertee and



Text-fig. 6.—Sketch map of south-eastern Australia showing area of Upper Devonian Sedimentation (Middle Stage).

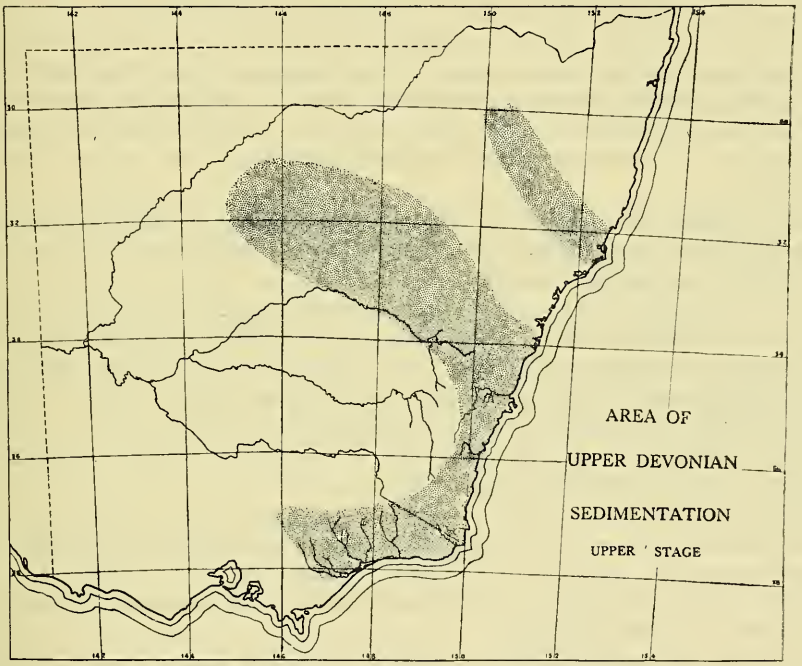
Mudgee. No centres of volcanic activity have been recognized; indeed, it seems more probable that the flows were due to fissure eruptions associated with faulting that preceded the formation of the depressed area in which the later sediments were deposited.

The probable position of this zone is indicated in Text-figure 6, and it forms the first approximation to the development of the important geosyncline in which the Upper Palaeozoic and Mesozoic sediments of eastern Australia were deposited. The gradual movement of the axis of the geosyncline to the north and east is an important tectonic feature in the building of Australia, which has been recognized by T. W. E. David (1893*a*) and E. C. Andrews (1914, 1916*b*).

The middle or Yalwal stage of the Upper Devonian followed the trend of the previous stage and consists of lacustrine or estuarine deposits, characterized by a

great development of red beds, mudstones, sandstones and grits, and contains fragmentary plant remains but no marine organisms. Igneous activity continued through the middle stage, rhyolites being interbedded with basalts allied to spilites.

Continued subsidence caused marine transgression over the greater part of New South Wales in the upper (Lambie) stage of the Upper Devonian (Text-fig. 7). The marginal trough of the previous stage appears to have survived, and the greatest sedimentation took place in this zone; arenaceous sediments of the order of 1,200 feet in thickness remain in the southern part of the State. At Mt. Lambie the thickness was somewhat greater, although recent work by Miss G. Joplin, B.Sc., and the writer indicates that previously the thickness of the Lambie series has been considerably over-estimated.



Text-fig. 7.—Sketch map of south-eastern Australia showing area of Upper Devonian Sedimentation (Upper Stage).
Note.—Other outcrops coloured as Devonian on the State Geological Map of New South Wales consist chiefly of unfossiliferous quartzites.

The lithology of this stage is characteristic: coarse conglomerates, purple sandstones and quartzites predominate. There appear to be no massive coralline limestones throughout the Upper Devonian. Marine fossils are abundant in certain thin zones, and may form local shell-beds, but great thicknesses of sediment are unfossiliferous. Drift *Lepidodendron australe* occurs in this stage.

Outliers of Upper Devonian rocks have been described from Molong-Canoblas (C. A. Süssmilch, 1906), Upper Macquarie (L. F. Harper, 1909*b*), Parkes-Forbes (E. C. Andrews, 1910), Cobar and Canbelego (E. C. Andrews, 1913*a*, 1913*b*), and Wellington, N.S.W. (A. J. Matheson, 1930), and other occurrences are recorded in Reports of the Geological Survey of the Mines Department, New South Wales.

Probably the Lambian sea extended almost as far west as the Darling River (Text-fig. 7) and a veneer of arenaceous sediments was deposited over the pre-Devonian rocks. In the Cretaceous conglomerates west of the Darling River, boulders of fossiliferous Upper Devonian rocks have been found (J. B. Jaquet, 1892; W. S. Dun, 1898*b*), but according to E. J. Kenny (1929, 1930), probably no outcrops of proved Devonian sediments occur beyond 50 miles west of Cobar.

No igneous flows are known to occur in the upper stage of Upper Devonian sedimentation, which was succeeded by a period of great orogenic earth-movement, termed by C. A. Süssmilch (1914) the Kanimbla Epoch. Folding of the Upper Devonian during this epoch was accompanied by the intrusion of enormous granodioritic batholiths in the area under consideration, and its description may well form a separate chapter in the geological history of the State.

Summary.

The paper describes the occurrence of the Devonian rocks of the South Coast of New South Wales, between the Shoalhaven River and the Victorian Border. The field-relations and associations of these rocks are described from a number of localities, and the petrological and chemical characters of the igneous rocks are discussed.

It is shown that the sediments were deposited unconformably on the older Palaeozoic formations, probably in a narrow geosynclinal trough, whose axis was inland from the present coast-line.

The rocks belong to the Upper Devonian Series, which is represented by three stages on the South Coast: a lower stage of acid volcanic rocks, a middle stage of freshwater or estuarine sediments with contemporaneous acid and basic lavas, and an upper stage of marine sediments containing no igneous rocks. These are called the Eden, Yalwal and Lambie Stages respectively.

The formations are correlated with a number of other occurrences of Devonian rocks in south-eastern Australia.

The discussion of the tectonic history of the series has led to a consideration of the palaeogeography of the Devonian system in south-eastern Australia. It is considered that the occurrence of the Snowy River porphyries, of Lower Devonian age, had a tectonic significance, indicating the position of subsequent deposition of the Middle Devonian sediments.

A survey of available literature suggests that the Middle Devonian gulf or sea was more extensive than has been supposed formerly, and that all the massive coralline limestones of Devonian age in New South Wales belong to the Middle Series.

The relations of the Middle and Upper Series have not been recorded in New South Wales, although a study of the palaeogeography indicates that their relations may be revealed in the Mudgee-Capertee and Goulburn-Tarago districts. It is considered that the unconformity at Tabberabbera, Victoria, is of more than local significance, being additional evidence of the diastrophism which finally welded on the south-eastern part of Australia to the growing continental mass. The trends of the Upper Devonian rocks on the South Coast are directed along the margin of this mass, and are the earliest indication of the position of the geosyncline in which the Permo-Carboniferous System of eastern Australia was deposited. During the upper (Lambie) stage of the Upper Devonian, represented

chiefly by arenaceous sediments, marine transgression took place over a considerable area in New South Wales.

The paper is illustrated by a series of palaeogeographical maps, and geological sketch-maps and sections of the Eden-Wolumla district and of the South Coast between the Shoalhaven River and the Victorian Border. For the latter maps the parish and county maps of the Department of Lands, Sydney, were used as a geographical basis. Some geological information was obtained for the area north of Bateman's Bay from L. F. Harper's map of the Southern Coalfield of New South Wales, 1915, and from reports of the Department of Mines, New South Wales. The results of the published work of the writer on the igneous rocks of the Milton (1925), Moruya (1928) and Mt. Dromedary (1930) districts are incorporated. Otherwise the mapping is the result of the writer's field-work, which has not been published previously. The known Devonian outcrops are distinguished from the older Palaeozoic sediments, and the outcrops of the granitic batholiths are shown more accurately than on the existing Geological Map of the State, although no specific reference to them has been made in the present paper.

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EXPLANATION OF PLATES XXX-XXXIV.

Plate xxx.

1.—Cliff below the Eden Lighthouse, showing the junction between the older Palaeozoic sediments and the overlying columnar rhyolite of Upper Devonian Age.

2.—Cliff section north of Tathra showing unconformity between the older Palaeozoic sediments and Upper Devonian rhyolite.

3.—Cliff south of the Eden Lighthouse, showing columnar structure in the rhyolite.

Plate xxxi.

1.—Section at "Edrom", Twofold Bay, showing the eroded upper surface of the rhyolite overlain by basal conglomerate of the middle stage of the Upper Devonian.

2.—Cliff section below the Convent, Eden, showing "red-beds" of the middle stage of the Upper Devonian deposited against the eroded surface of the rhyolite of the lower stage (see text).

3.—Road cutting, 22 miles from Moruya towards Araluen, showing ripple-marks in highly-folded Upper Devonian sediments.

Plate xxxii.

1.—Rock-platform at Munganno Point, Twofold Bay, showing large spherulites in rhyolite.

2.—Polished section of large spherulite from Munganno Point, showing central amygdule of banded chalcedony, concentric secondary structure of the spherulite, which has not entirely obliterated the original flow-lines of the rhyolite. $\frac{3}{4}$ natural size. Photo. H. G. Gooch.

Plate xxxiii.

Geological Sketch Map of the Eden District.

Plate xxxiv.

Geological Sketch Map of the South Coast between the Shoalhaven River and the Victorian Border.